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UML Diagrams for Task Analysis to Improve Human System Interface Design for a Operator Support System

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1. Introduction

Task analysis occupies an important position in system development. Task analysis, which is recognized as the most important step in Human Centered Design (HCD), has been presented in many methodologies according to the times and domains. As the industry became automated and digitized, the trend of task analysis expanded to the area of cognitive task analysis, but the basic principles and frameworks for deriving the requirements necessary for task performance from the perspective of users by looking into the task are maintained.

In this report, we would like to try a new methodology and present the results obtained by breaking away from the hierarchical task analysis (HTA) that has been widely performed in academia, research, and industry. Hierarchical task analysis is one of the traditional methods in which task analysis has been used at the same time as it has established itself as a pivotal role in the analysis stage required for development. In general, its applicability is not often insufficient, and it is also a method still used in the field of nuclear power without much inconvenience. However, because it is a method that has been used for a long time, there are questions about other methodologies, and the limitations of using hierarchical job analysis were sometimes disappointing, so other methodologies were sought.

This study was conducted in the process of exploring new task analysis methods in the activities of developing an artificial intelligence (AI)-based support system that supports the decision-making of nuclear power plant main control room operators.

With the digitization of the industry, the proportion and importance of software in the system have continued to expand. Accordingly, software development has gradually occupied a wide core area in system development, and the software development methodology is also recognized as an important development technology. In the field of software development, task analysis is performed directly in the analysis stage for system development, but in most cases, the analysis of the user is included in the structure and functional analysis of all elements related to the system. Various analysis methods are presented for each element, and the unified modeling language (UML) of OMG (object management group) has the advantage of being easy to understand as standardizing visualization of the system based on object-oriented concepts

This paper provides technical information on the task analysis method performed in the development process of the main control room operator decision support system of a nuclear power plant. The commonly used task analysis method is called hierarchical task analysis. With the digitization of the main control room of nuclear power plants, the operator user interface has also been digitized, and the actual operator interface is being implemented around software. A representative example is the soft control (SC) applied to the operator workstation. Reflecting this trend, the development project attempted to use the techniques used in the system and software development methods for task analysis.

The representative modeling techniques used in the conceptual design stage are OMG's UML, and in this study, the activity diagram (AD) and sequence diagram (SD), which were judged to be appropriate for the purpose and method of task analysis, were attempted. This paper describes this attempt process sequentially and provides evaluation and lessons on the results obtained in the implementation process.

2. Methods and Results

In the first phase of the main project, an HSI prototype was developed. However, this prototype was primarily intended to confirm the developers' efforts in the initial R\&D stage and to provide an indication of accuracy and applicability, rather than being systematically designed with actual users in mind. In the second phase, a pilot system will be developed, and the focus will shift toward implementing genuine user-centered design.

The decision support system under development aims primarily to assist main control room operators in distinguishing between normal and abnormal plant conditions. This is critical, as it subsequently supports operators in determining appropriate response actions.

For the task analysis, input materials included the first-phase decision support system prototype (documents and videos) and eight scenario descriptions.

The prototype was created within a simulator-linked environment to illustrate, in a sequential use case format, how support functions (e.g., signal verification, state diagnosis, diagnostic prediction, and reaction support) would operate in assumed real situations. It demonstrates functions such as malfunction injection to simulate transitions from normal to abnormal states, display of diagnostic results, variable contributions to diagnosis, diagnostic accuracy, trend projection of key variables, and provision of procedural guidance and cautions.

Since the prototype primarily exposes the internal workings of support functions, its design elements for user interaction are relatively limited. The current task analysis, therefore, aims to identify operators' information needs from an operator/user perspective and incorporate them into the improved HSI design. In other words, this task analysis is conducted not for developing an entirely new system, but rather for enhancing the design of the existing or partially developed system. This distinction has a direct impact on the selection of the task analysis method.

The task analysis was carried out under the premise that the design and implementation of decision support functions for nuclear power plant main control room operators would not go beyond the scope developed in the first phase(ended in 2024). This is because the second phase will focus on performance enhancement (fine-tuning) rather than major changes to the fundamental AI models or the range of events to be addressed.

For the task analysis of the eight abnormal scenarios, four analysts participated. Each analyst, who was knowledgeable about the operator decision support system, nuclear power plant processes, and abnormal operating procedures, was assigned two abnormal scenarios and prepared an Activity Diagram (AD) and a Sequence Diagram (SD) for them. Since this was their first attempt at developing such diagrams, they agreed to refine and integrate the diagrams iteratively through repeated efforts. Fig. 1 and 2. shows an AD and a SD written for abnormal scenarios.

3. Conclusions

The key question addressed in this study was whether diagram-based task analysis using UML is effective. Traditionally, Hierarchical Task Analysis (HTA) has been employed in nuclear HSI design, but in this study, UML diagrams—Activity Diagrams (AD) and Sequence Diagrams (SD)—were applied as an alternative approach, since the purpose was not to develop a new system but to improve an existing prototype. The results showed that UML-based task analysis was effective in deriving task decompositions and task requirements, and can be recommended as a viable alternative in similar contexts.

In comparing HTA with AD and SD, several strengths and weaknesses were identified (refer to Table I). HTA has the advantages of being easy to initiate—especially when procedure-based inputs are available—requiring fewer technical skills, and benefiting from the availability of experienced analysts. By contrast, AD and SD require specialized knowledge and tool standardization, which can make the learning and application process more time-consuming. However, AD and SD provide significant benefits: they can explicitly represent conditions (e.g., conditional, iterative, or parallel tasks) and capture task interactions and information flows, aspects that HTA does not handle well. Thus, for tasks where interaction is critical, SD is particularly valuable.

A hybrid approach combining HTA with AD and SD was suggested as highly useful: HTA offers a good starting point for decomposition, while AD and SD enrich the analysis with detailed representation of task flows and interaction requirements. This combination, however, requires sufficient resources, as it can be labor-intensive.

This study also emphasized the importance of analyst consensus when using AD and SD, particularly regarding tools and diagram shapes. In this research, analysts engaged in discussions and reached agreement after the initial drafts, underscoring the necessity of this step when multiple analysts are involved.

Another observation is that the analysis method should match the development context. For example, in this study, some procedural support steps were simplified because the goal was to improve an existing interface prototype, not to design a completely new system.

Finally, task analysis serves not only to derive functional requirements and support HSI design but also to deepen the understanding of tasks among analysts, designers, and developers. UML diagrams, being familiar to many developers with software backgrounds, can facilitate communication and knowledge transfer between task analysts and design teams. Therefore, AD- and SD-based task analysis can function as an efficient medium for design collaboration and information sharing.

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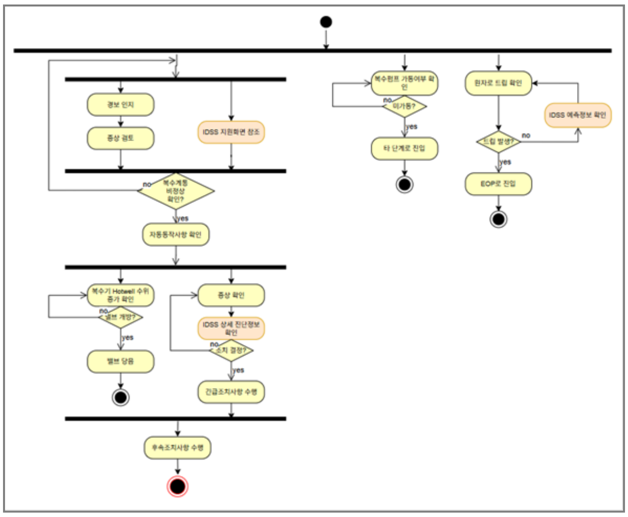

Fig. 1. An example of Activity Diagram depicted for an abnormal scenario

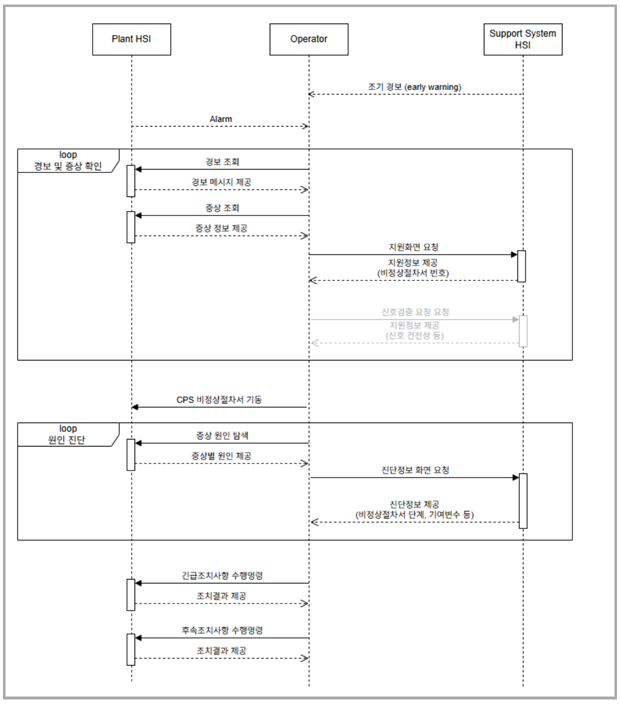

Fig. 2. An example of Sequence Diagram depicted for an abnormal scenario

Table I: Comparison of HTA and UML-based Task Analysis (AD, SD)

Aspect	**HTA (Hierarchical Task Analysis)**	**UML-based Analysis (AD, SD)**
Strengths	- Easy to initiate based on abnormal operating procedures - Requires minimal technical training or tools - Experienced analysts readily available - Provides intuitive and simple hierarchical/linear representations - Results are easy to understand	- Effectively represents conditions (conditional, iterative, parallel tasks) - Captures interactions and information flows, addressing HTA limitations - Familiar to designers/developers with software background, facilitating communication - Useful for generating design improvement insights - Serves as a medium for collaboration and information sharing
Weaknesses	- Limited in expressing conditional, repetitive, or parallel tasks - Insufficient representation of interactions and information flows - Less effective in identifying design improvement directions	- Requires learning and training, consuming time and effort - Necessitates agreement on standardized tools and diagram shapes - Few analysts in nuclear domain with prior experience - Can be resource-intensive in terms of time and manpower
Best-suited situation	- Functional definition and basic task decomposition - As a starting point for analysis - Situations requiring quick analysis under limited resources	- When the primary goal is design improvement - When interactions and information flows are critical - When close collaboration with designers and developers is needed